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Influence of Air Mass on the Performance of Many Types of PV Modulus in Baghdad

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Abstract This paper presents the results of the outdoor performance tests for several types of commercial photovoltaic panels. These were both single crystal and multicrystalline silicon (Si) panels as well as thin-film crystalline (CIS) and two amorphous Si devices-single junction, marked as TJ, respectively. The effects of air mass and thus solar time on the performance of the above types of solar cell panels was evaluated for twelve months from year in Baghdad (Latitude 33^{o}) to find the best type of solar panels which suitable with the annual applications according to geographic position of Baghdad. The results of theoretical calculations show that the performance of triple-junction amorphous NIST insulated (TJ-NIST-I) and triple-junction amorphous SNL uninsulated (TJ-SNL-UN) are the best type than others at small air mass for eight months from year, while at large air mass the other types give large maximum output power than NIST insulated and SNL uninsulated.

Solar cell , Photovoltaic panels, Air mass, Solar time

1. Introduction

The characterization of the performance of the photovoltaic panels do not take into account the effects of such environmental factors as insulation level, solar spectrum and other meteorological conditions. Due to natural spectral sensitivity of solar cell devices, the solar spectrum is one of those environmental factors which may strongly influence to the panel's performance. since the solar spectrum depends on the sun's actual altitude and declination, so it means that must be given up both to seasonal

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changes during the year as well as to much faster periodic changes during each day. Actual solar spectrum is usually quantified by using so called air mass (Am) factor which is the parameter describes the shape of solar spectrum by filters and scatters solar radiation reaching the Earth's surface [1].

2. Theoretical

2.1 The Solar Spectrum

The solar spectrum is one of the electromagnetic spectrum which represented all waves that involve electromagnetic fields. The solar radiation spectrum corresponds to the sun's surface temperature which is between (5700-5900)^{o}C (i.e., the emitted solar spectrum as seen in space is equivalent to the Spectrum of EM radiation emitted by a black body radiation held at that temperature). As viewed on Earth it is shifted slightly from the black body radiation spectrum, due to the scattering of blue light and the absorption of red light by the atmospheric. Fig.1. shows the extraterrestrial solar radiation spectrum observed through the atmosphere and the solar radiation after entering the atmosphere which show the scattering and absorption processes by atmospheric aerosols [2].

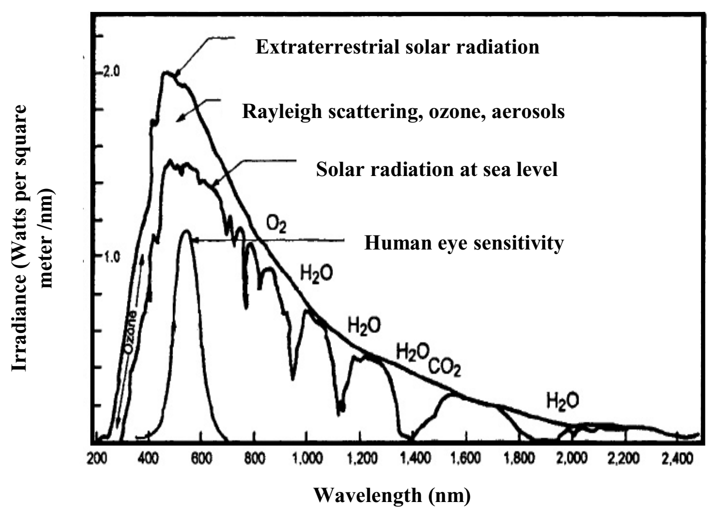

Fig.1.Solar radiation spectrum in space and after entering the atmosphere [2].

2.2 Air Mass

Air mass is defined as the relative length of the direct-beam path through the atmosphere compared with a vertical path directly to Sea level. For an ideal homogenous atmosphere, simple geometrical considerations lead to:

$$AM=1/\cos z_S \qquad (1)$$

where AM is the air mass and z_s is the zenith angle of sun. Fig.2. shows the effect of air mass. At the standard atmosphere AM_1 after absorption has been accounted for the normal irradiance is generally reduced from extraterrestrial solar radiation to 1000 W/m^2 which is just the value used for the standard test of PV devices. The different air mass values show that decrease the visible spectrum of solar radiation which represented the most spectrum for solar cell work[3]. Fig.3. shows the distribution of air mass from sunrise to sunset for twelve months in Baghdad (Latitude 33°).

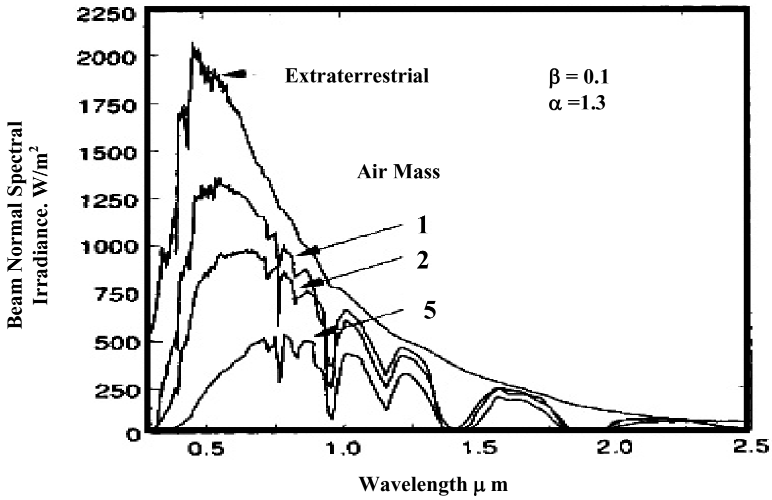

Fig.2. The spectral distribution of beam irradiance for air masses (0, 1, 2 and 5) [3].

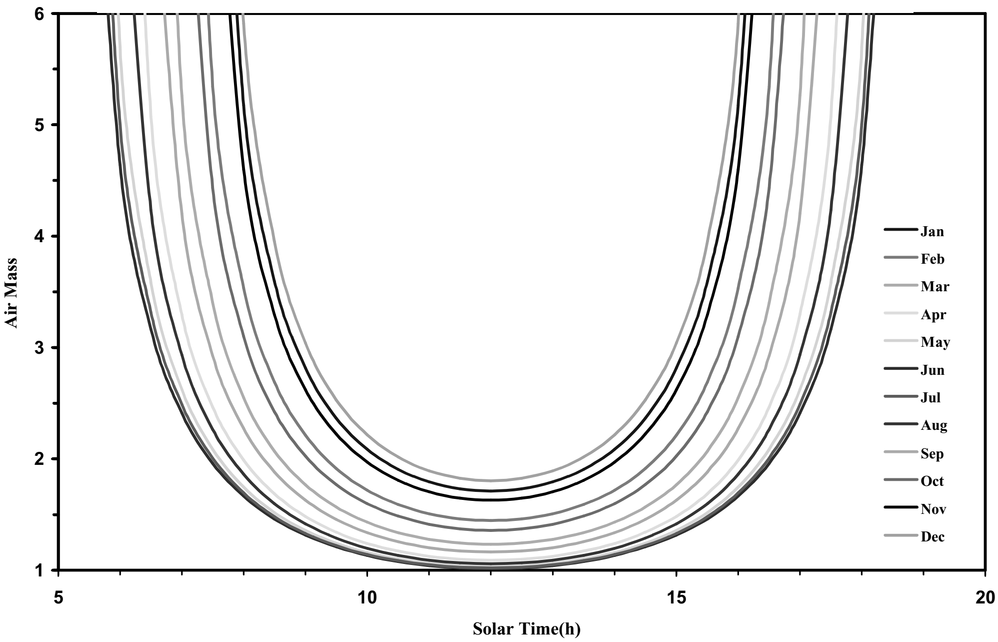

Fig.3. The variation of air mass with solar time for twelve months in Baghdad.

2.3 Performance equations of solar panels

The following equations define the electrical performance of photovoltaic panels. The same equations apply equally well for individual cells and for large arrays of panels. The equations 2 to 10 are used to calculate the expected I_{sc},V_{oc} and P_m produced by a panel. The solar resource and weather data required in these equations can be obtained from NASA Langley Research Center or from direct measurements [4]:

$$I_{SC}=I_{SCO}f_1(AM)(H_bf_2(AOI)+f_dH_d)/H_r)(1+\alpha_{ISC}(T_C-T_O) \quad (2)$$

$$V_{OC}=V_{OCO}+N_S\delta(T_C)\ ln(H_e)\ +\beta_{VOC}(T_C-T_C) \quad (3)$$

$$P_m = I_m\ V_m = FF\ I_{sc}\ V_{oc} \quad (4)$$

$$H_e=I_{SC}/I_{SCO} \quad (5)$$

Where I_{SC}, I_m are the short circuit and maximum current respectively (A). I_{SCO} is the short circuit current under standard test conditions {H_t = 1000 W/m^2, T_c = T_o °C, AM = 1.5, AIO = 0°} (A). AM: is the air mass. AIO: is the solar angle of incidence. V_{oc}, V_m are the open circuit and maximum voltage, respectively (V). V_{oco}: is the open circuit voltage under standard test conditions (V). P_m: is the maximum output power (W).FF is the fill factor of the solar cell panel. H_b: is the beam solar irradiance (W/m^2). H_r is the reference solar irradiance, typically, 1000 (W/m^2). $H_d$is the diffuse solar irradiance (W/m^2). H_e is the effective irradiance. H_t is the total solar irradiance (beam + diffuse (W/m^2). N_s is the number of cells connected in series in a panel. T_C: is the cell temperature inside panel (°C).T_o is the reference temperature for cells in panel, typically, 25°C. f_d is the fraction of diffuse irradiance used by panel, typically assumed to be one for flat plate panels and zero for concentrating systems. β_{voc} is the V_{OC} temperature coefficient (V/°C). α_{Isc} is the I_{sc} temperature coefficient (A/°C). f_1(AM) is the empirically determined "AM function" for solar spectral influence. F_2(AOI) is the empirically determined "AOI function" for angle of incidence affects. $\delta(T_c)$ is the thermal voltage per cell at temperature T_c. The equations used to calculate f_1(AM, F_2(AOI), $\delta(T_c)$, H_b, and T_C can be written as follows [5].

$$f_1(AOI)=a_o+a_1(AOI)+a_2(AOI)^2+a_3(AOI)^3+a_4(AOI)^4 \quad (6)$$

$$f_2(AOI)=b_o+b_1(AOI)+b_2(AOI)^2+b_3(AOI)^3+b_4(AOI)^4\ \ +b_5(AOI)^5 \quad (7)$$

$$H_b=H_{b,\ N}cos\ (AOI) \quad (8)$$

$$T_C=T_a+H_t(e^{\ a+bWS}) \quad (9)$$

$$\delta(T_C) = mK\ (T_C + 273.15)/q \quad (10)$$

where a_o to a_4 and b_o to b_5 are the air mass and angle of incidence coefficients respectively, $H_{b,N}$ is the beam normal irradiance (W/m^2), T_a is the ambient temperature (°C), a and b are the temperature coefficient specified for used solar cell panel, ws is the wind speed in (m/s), m is the diode factor, typically near unity, K is the Boltzmann constant and q is the elementary charge. The electrical characteristics of solar panel under standard test conditions and the coefficients required in the mathematical equations for the used solar cell panels are listed in tables (1) and (2).

Table (1): Summary of used solar cell panels coefficient [5].

a_o	a_1	a_2	a_3	a_4
0.938	0.0622	-0.01500	0.001220	-0.0000340
0.939	0.0552	-0.01090	0.000813	-0.0000235
0.931	0.0674	-0.01690	0.001530	-0.0000552
0.936	0.0543	-0.00868	0.000527	-0.0000110
0.925	0.0689	-0.01390	0.001150	-0.0000383
1.100	-0.0614	-0.00443	0.000632	-0.0000192
0.982	0.0588	-0.03730	0.004120	-0.0001470

Table(2): Electrical characteristics of used solar cell panel at standard test conditions (STC) and temperature coefficient [5].

Symbol	I_{sco}	V_{oco}	I_{mo}	V_{mo}	FF	α_{Isc}	B_{Voc}	a	b	N_s
value	5.35	22.05	4.85	17.49	0.71	1.02E-03	-1.41 E-01	-3.47	-0.59	44

A fundamental parameters I_{mp}, V_{mp}, and V_{OC} of a panel are behaved and predictable when described as a function of I_{SC} and cell temperature only, in other words, for a given I_{SC} and cell temperature the shape of the current-voltage curve will be the same for any solar spectrum and angle of incidence [6].

3. Results and Discussion

The performance of the solar panels depends on many factors such as air mass which effect on the spectral distribution reaching the Earth or the solar panel surface. In this paper the performance of seven types of solar cell panels was evaluated by studying the effects of air mass and thus the solar time on the maximum output power for twelve months from January to December in Baghdad (Latitude 33^o). Figs .4. show the relation between maximum output power with solar time and air mass for Jun. and Dec. months . The general behaviour of all these figures are the exponential degradation of the maximum output power with increasing the air mass. The results of theoretical calculations show that the performance of triple-junction amorphous NIST insulated (TJ-NIST-I) and triple-junction amorphous SNL uninsulated (TJ-SNL-UN) are the best type than others at small air mass for eight months from year, while at large air mass the other types give large maximum output power than NIST insulated and SNL uninsulated because the effect of band gap of these types which determine the range of work wavelength of these materials and the effect of air mass in reduce some wavelengths of solar radiation. The other curves shows the Gaussian distribution of maximum output power with solar time. The top of the curve is got at solar noon when the sun at high altitude in the sky in the south and at low air mass.

Fig.5. shows relation between the maximum output power with solar time which represented by Gaussian distribution for Si (NIST-I). This curves show that the best month gives the high value of maximum output power is June because there are many reasons. The first is, in this month the day length is more long than the days of other months, the second is, the low value of air mass and high value of solar altitude angle which makes the solar radiation pass through short optical path and decrease the effect of scattering and absorption by the atmospheric aerosols.

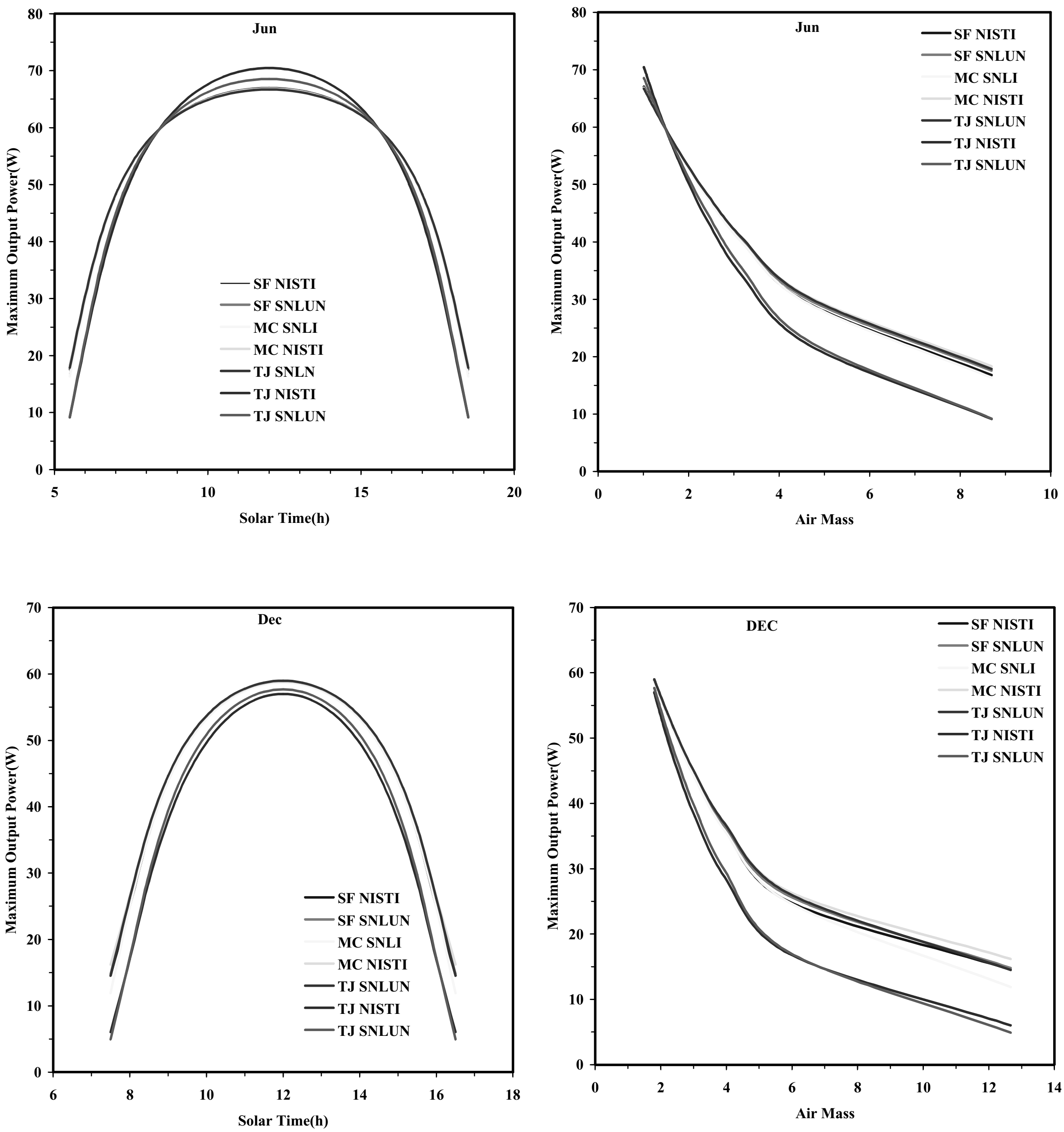

Fig.4. The variation of maximum output power with solar time and air mass for four months Jun. and Dec. in Baghdad.

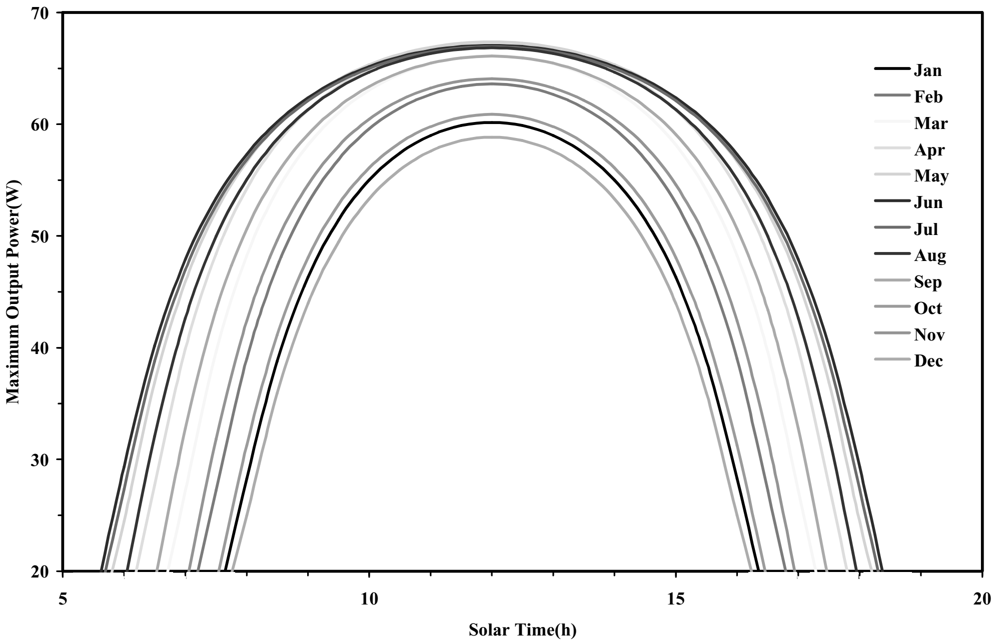

Fig.5. The variation of air maximum output power with solar time for twelve months in Baghdad.

4. Conclusion

There are many conclusions of this paper:

1. June is the best month which gives high performance of solar panels.
2.The performance of triple-junction amorphous NIST insulated (TJ-NIST-I) and triple-junction amorphous SNL uninsulated (TJ-SNL-UN) are the best type than others at small air mass for eight months from year.
3.At large air mass the other types give large maximum output power than NIST insulated and SNL uninsulated

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